TCP/IP OVER HIGH DELAY AND ASYMMETRIC MEDIA

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Factors Affecting TCP Throughput in Challenging Environments

Factor	Terrestrial Link	GEO Satellite	VSAT Solution
Bit Error Rate	$< 10^{-9}$	10^{-5} to 10^{-12}	Proper link design, BER = 10^{-9}
Round Trip Delay	Milliseconds to seconds	Seconds	TCP Spoofing Large windows
Continuity of Connectivity	Continuous	Intermittent during rain-fades	Intermittence is mitigated with proper link design
Forward and Reverse Links	1:1 (Equivalent Rates)	2:1 to 100:1	Rate control Ack filtering strategy
Communication Goals	Fair access over time High aggregate throughput over time High reliability	High throughput during contact periods Maximum link utilization	< 400 Kbit/s throughput Modification to congestion response and slow start Data compression
Primary Sources of Data Loss	Congestion	Congestion Corruption Link outage	Effects of corruption and link outages are mitigated with proper link design

Network Response-Times

- **125 ms - transcontinental access across the Internet from two-well connected(T1) sites, on a good day**

- **300 ms - transcontinental access across the Internet from a dialup modem to a well-connected server.**

- **500 ms - DirecPC Personal Edition transcontinental Internet access (dialup-in, satellite back-haul)**

- **700 ms - Personal Earth Station w/User Aloha**

- **1650 ms - Personal Earth Station w/Reservation Inroute Access**

- **DirecPC Enterprise Edition - same as Personal Earth Station**

PES Inroutes And Outroutes

- **Personal Earth Station**
  - **Outroute: 128/512 kbits/s**
  - **Inroute: 64/128/256 Kbits/s**
- **DirecPC Personal Edition**
  - **Outroute: 24 Mbit/s**
  - **Inroute: telephone modem**
- **DirecPC Enterprise Edition**
  - **Outroute: 3 to 24 Mbit/s**
  - **Inroute: 64/128/256 Kbits/s**
- **HNS customers have networks with 4,000 sites, 8 outroutes, 47 inroutes**

Window Size Limits Throughput

- **Maximum throughput = Window Size / Round-Trip Delay**

Examples:

PES w/Reservation max throughput with default window sizes = 8 Kbytes / 1.65 sec = 4.85 Kbyte/sec = 39 Kbits/sec

DirecPC Personal Edition = 48 Kbytes/ .5 sec = 768 Kbits/sec

Mitigating Techniques

- **TCP Spoofing**

- **Web Caching**

- **ACK Filtering and Congestion Control**

- **Data Compression**

Further information on mitigating factors under study/research:
ftp://ftp.ietf.org/internet-drafts/drafts-ietf-tcpsat-res-issues-05.txt

DirecPC System Architecture

THE INTERNET
(CONVENTIONAL TCP/IP NETWORK)

DirecPC™ NETWORK
(HYBRID TCP/IP NETWORK)

ACK 3450
ACK 2875
ACK 2300
ACK 1725
ACK 1150

SPECIAL NDIS DRIVER

ACK 3450
ACK 1150

ACK 2875
ACK 2300
ACK 1725

TRASH

RTT_1

WIN_2

DATA

DATA

LARGE
BUFFER
SPACE

$RTT_2 \gg RTT_1$

WIN_1

DATA

THE GATEWAY ACKs
TO THE INCOMING DATA

APPLICATION
SERVER

HUGHES
NETWORK SYSTEMS
DirecPC GATEWAY

THE TERMINAL ACKs
TO THE INCOMING DATA
FROM THE GATEWAY

DirecPC
TERMINAL

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